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Specification as originally filed, with Application for Patent Serial No: **2,337,737**, on February 22, 2001, by **CATENA NETWORKS CANADA INC.**, assignee of Alberto Ginesi and Andrew Deczky, for "Improved Method of Adapting the Receiver Demodulation Structure According to the Transmitter IFFT Size, in DMT-Based ADSL Modems".

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Date

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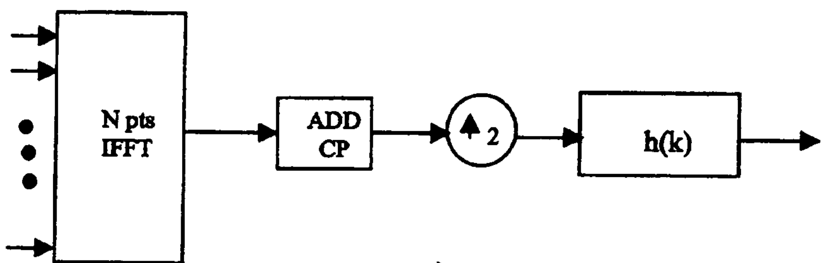
ABSTRACT

For several reasons some current G.992.1 and G.992.2 modems implement the transmitter (either the U/S or the D/S) with an IFFT size greater than the one specified by the Standard. If the images of the transmit signal are correctly replicated with period equal to the clock frequency of the Standard IFFTs (276 kHz for U/S and 2208 kHz for D/S), no difference is of course observed as the in this case the transmit signal is exactly the same as the one generated by a Standard-size IFFT. However, this does not occur in some of the G.992.x modems. Even though this does not compromise interoperability, if the receiver is not made aware of the way the transmit signal is generated inter-performance may be affected, particularly on short loops.

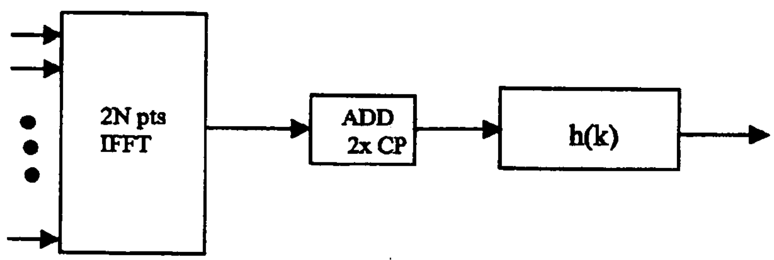
1. Introduction

It is well known that some current G.992.1 and G.992.2 modems implement the transmitter (either the U/S or the D/S) with an IFFT size greater than the one specified by the Standard. There are many reasons behind this choice. In particular, for the U/S channel an IFFT greater than 64 points may be justified by mainly two reasons: i) HW symmetry with the D/S channel; ii) ease the implementation of the different Annexes of G.992.1 and G.992.2 with the same data path. If the images of the transmit signal are correctly replicated with period equal to the clock frequency of the Standard IFFTs (276 kHz for U/S and 2208 kHz for D/S), no difference is of course observed as the in this case the transmit signal is exactly the same as the one generated by a Standard-size IFFT. However, this does not occur in some of the G.992.x modems. Even though this does not compromise interoperability, if the receiver is not made aware of the way the transmit signal is generated inter-performance may be affected, particularly on short loops.

In order to understand the issue, let us consider Figure 1, where a Standard-size IFFT transmitter is shown together with a double size IFFT transmitter. No signal image restoration is supposed to be performed in the b) scheme.



a)



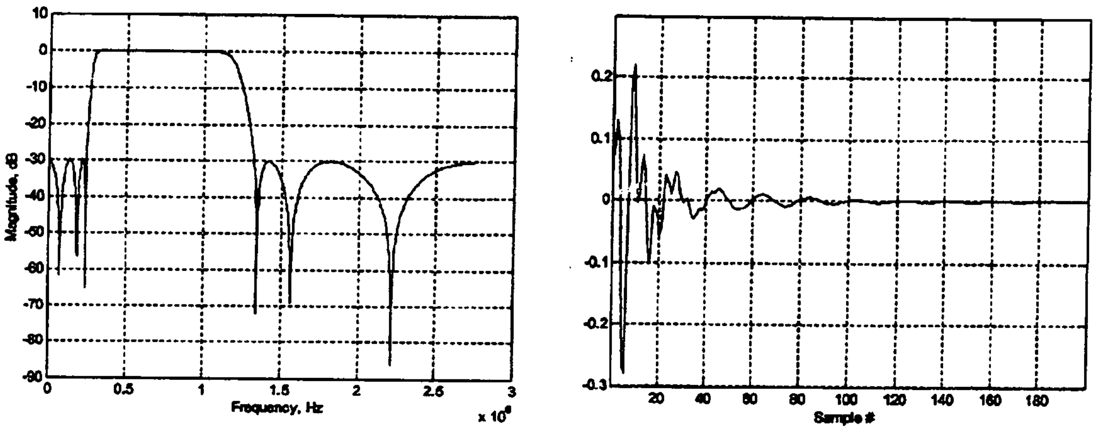
b)

Figure 1: a) N-pts IFFT followed by CP insertion, upsampling by 2 and filtering by h(k)
b) 2N-pts IFFT followed by 2xCP insertion, filtering by h(k)

In Figure 1 h(k) represents the channel and the transmit front end filters all merged into just one filter whose impulse response is sampled at a certain sampling frequency (twice the N-pts IFFT clock frequency). Scheme a) uses an N-point IFFT so, after adding the CP (Cyclic Prefix), an upsampling by 2 is needed to get to the channel sampling frequency. Scheme b) starts with a double size IFFT and it adds twice the number of samples for the Cyclic Prefix. While the two schemes generate the same identical signal while transmitting constant QAM symbols (REVERB-like DMT symbols), it is easily seen that the two generated signals are different in ShowTime mode.

Let us consider an example related to the U/S channel. In particular, let us assume that the channel is placed at 552 kHz sampling frequency and its frequency response and impulse response be the ones shown in Figure 2a) and 2b) respectively. In this example, the channel has been designed as a 6[th] order Chebyshev type 2 band-pass filter with 30 dB

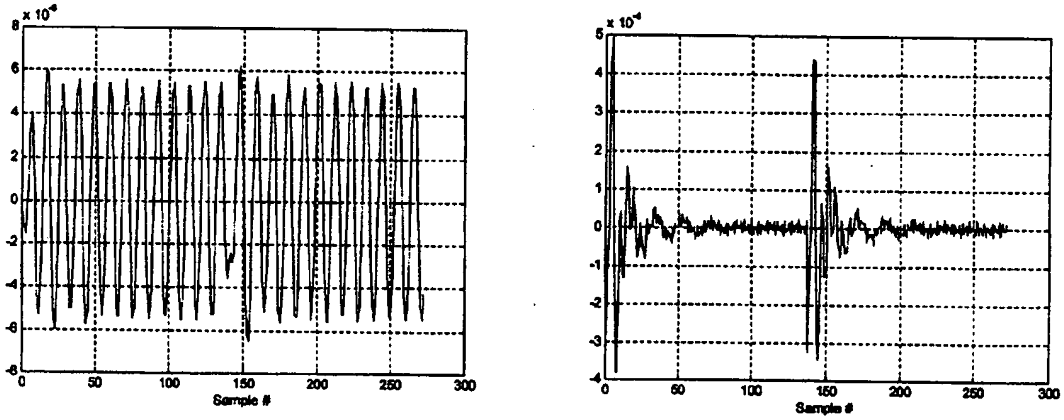
stop-band rejection. For the case of scheme a) N is 64 and CP is 4 samples. For the scheme b) the IFFT has 128 points and the Cyclic Prefix has 8 samples.



a) b)

Figure 2: a) Amplitude frequency response of the filter h(k). b) Impulse response h(k)

For simplicity, let us also assume to transmit only one bin, say bin 12, and collect the output of the two schemes of Figure 1) when the following two QAM symbols are transmitted into two consecutive DMT symbols: 1+j, -1-j. Figure 3a) shows the output of the system of Figure 1a) while Figure 3b) shows the delta between the output signals of the two systems



a) b)

Figure 3: a) Signal at the output of the system of Figure 1a); b) Difference between the two signals at the output of the systems of Figure 1a) and 1b).

As shown, the difference between the two output signals is small and is concentrated around the CP regions. Figure 4) shows the frequency content of Figure 3a). It is clear from there that the error signal between the two systems of Figure 1) does not have only high frequency components (frequencies greater than 138kHz) as one might have thought by inspection of the systems of Figure 1.

Our lab tests show that if the receiver is not made aware of the way the transmit signal is generated, on short loops data

rate penalties of ~25-30% are experienced. Instead, if the receiver knows whether the images of the transmit signal are present or not it can adapt its FFT size accordingly. If the images are present, then it would use a Standard-size FFT, otherwise it would use a bigger FFT size (at least tow times the Standard size). The latter involves changing the clock frequency of the Time Domain Equalizer (TDEQ) in the receiver.

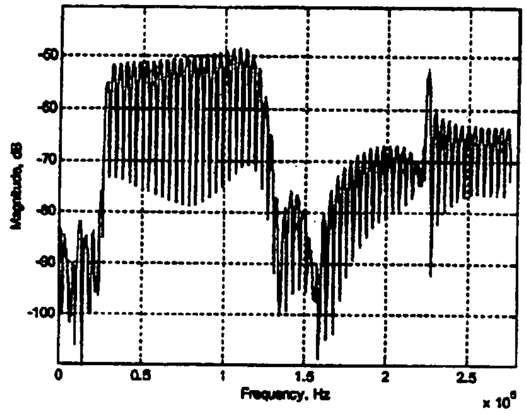
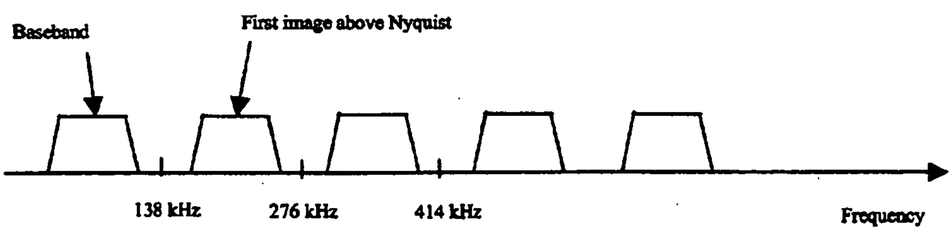


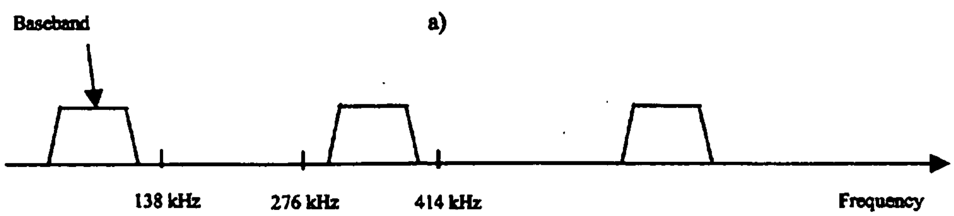
Figure 4: Spectrum of the signal of Figure 3b)

2. Claim

We propose to have some information exchanged between ATU-R and ATU-C in G.hs in order to let the receivers know how the transmit signals are being generated. This way the receiver can adapt its FFT size to adequately process the received signal: if the images of the transmit signal above the Nyquist frequency are present, then it would use a Standard-size FFT, otherwise it would use a bigger FFT size (at least tow times the Standard size). The latter involves changing the clock frequency of the Time Domain Equalizer (TDEQ) in the receiver.
The figure below illustrates the concept for the U/S channel: in the case of Figure 5a) the receiver would use a 64pts FFT; for the case of Figure 5b) the receiver would use a 128pts FFT.



a)



b)

Figure 5 – Spectrum of the U/S signal at the output of a 64pts IFFT (a) and 128 pts IFFT (b)